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Abstract

Purpose: To prospectively evaluate the long-term outcomes after a telementoring program for distant teaching of endovascular aneurysm repair (EVAR) and the degree of EVAR procedure assimilation into routine practice. **Methods:** A telementoring protocol using stepwise introduction of EVAR was implemented between a university care center and a remote vascular health care site; from March 1999 to October 2003, 49 EVAR patients (mean age 72 years; 48 men) were treated during telementoring at the remote center. After the telementoring period, 86 patients (mean age 71 years; 77 men) underwent EVAR procedures carried out at the secondary care center from November 2003 to July 2011. The long-term outcomes were compared between the EVAR procedures performed during telementoring with the procedures performed independently thereafter. **Results:** No significant difference was appreciated between telementored and not telementored procedures either in 30-day mortality (4.1% vs 2.3%, p=0.621) or in the initial technical success (93.9% vs 97.7%, p=0.353). The telementored group showed no significant difference in overall aneurysm-related mortality (6.1% vs 2.3%, p=0.353) or in the overall complication rates (p=0.985). The reintervention rate was significantly lower among the unmentored procedures (11.6% vs 32.7%, p=0.004). In particular, significantly fewer patients underwent late endovascular procedures (1.2% vs 12.2%, p=0.009) and late percutaneous interventions (7.0% vs 20.4%, p=0.027) after telementoring ceased. **Conclusion:** The telementoring program followed here allowed excellent EVAR skill assimilation into the routine practice of a remote health care site. Telementoring is a feasible strategy to support skill introduction in remote medical facilities.

Keywords

abdominal aortic aneurysm, distant teaching, endovascular aneurysm repair, remote teaching, telementoring

Introduction

First devised in 1996 by surgeons from the Johns Hopkins University group,[1,2] telementoring still represents an effective alternative to the cost, time, and geographical limitations associated with on-site teaching and technical skill training.[2] Providing methodological guidance and technical support from mentors located remotely,[2] telementoring delivers the requested medical service cheaply, at the desired time, and despite geographical distances.[1,3] For this reason, as predicted by Doarn,[4] telementoring has become a "natural fit" in today's surgical and less invasive interventional fields.

In particular, open surgical strategies are increasingly being replaced by minimally invasive approaches that are being disseminated from tertiary care centers to remote health care sites.[2] This phenomenon has created a further opportunity for telementoring due to the need for training of the operators and local teams in these remote hospitals.[2]

In Switzerland, a similar experience occurred in Canton Ticino, the only canton of the Swiss Federation located in the southern part of the Alps, where endovascular repair of abdominal aortic aneurysms (AAA) had been introduced into community practice through a well-established telementoring program.[6] For a population of about 330,000 inhabitants, only 3 public hospitals performed open surgical

AAA repair in Canton Ticino through 1998, with no institution performing EVAR. This unavailability forced AAA patients to travel to distant institutions located beyond the Alps to undergo EVAR treatment. For this reason, a telementoring protocol[6] was initiated in 1999 at the University Hospital of Lausanne's tertiary care center, located in Canton Vaud, for the stepwise introduction of EVAR at the San Giovanni Hospital of Bellinzona, a secondary care center located in Canton Ticino. This was feasible at the time because Switzerland was one of the first European countries to run ISDN (Integrated Services Digital Network) lines, which allowed the data and image transmission needed to support the telementored EVAR procedures performed during our prospective project.[6]

The current study reports the prospective evaluation of the EVAR outcomes after the telementoring program at the remote secondary center and the EVAR procedure skills assimilated into routine community practice over 10 years.

Methods

Study Population

As described in our previous work,[6] from March 1999 to October 2003 a telementoring protocol to train operators and teams in EVAR techniques was in effect between the University Hospital of Lausanne and the San Giovanni Hospital of Bellinzona. During this learning period, 49 AAA patients (mean age 72 years; 48 men) were prospectively enrolled at the secondary care center to undergo telementored EVAR. Indications for EVAR were (1) saccular or fusiform aneurysms with a ≥50-mm diameter or rapid progression (>5 mm/y); (2) a proximal neck ≥10 mm long, ≤30 mm in diameter, and with <60° angulation; (3) at least one 6.5-mm-diameter external iliac artery; and (4) a maximum 20-mm-diameter distal landing zone.[7]

After the telementoring period, 86 patients (mean age 71 years; 77 men) underwent EVAR procedures carried out at the secondary care center from November 2003 to July 2011 and were monitored in an ongoing assessment protocol. The AAA eligibility criteria for EVAR were the same as during the telementoring period. Clinical and radiological follow-up was monitored until May 2013. Patient characteristics for both groups are summarized in Table 1. All patients enrolled in the study, which was conducted in accord with the Declaration of Helsinki, signed a written informed consent that was approved by the local ethics committee.

Telementoring Program

As detailed previously,[6] data transmission was achieved through a commercial videoconference system (Eykona; Aethra S.p.A., Ancona, Italy) using 4 ISDN lines (rate of transmission 384 kb/s) to ensure secure 2-way audio communications throughout the intervention.[6] Video compression standards H.320 and H.261 guided digitization of analog image signals.[6] Feedback from the telementored site was supported by 3 video facilities that captured the intravascular ultrasound (IVUS) images, the fluoroscopic images, and a panoramic view of the operating theatre, respectively (also allowing zoom during the procedure). Small cameras installed on the ceiling of the operating room and above the operating table allowed adequate views of the operating theatre. The telementored staff was also equipped with a single view of the mentor (L.K.v.S), allowing distant assistance during the entire EVAR procedure. The local medical staff consisted of a vascular surgeon, an experienced interventional radiologist, and an interventional cardiologist (the latter 2 with very limited experiences in EVAR).

Preoperative Workup

Our well established preoperative protocol[7,8] involved computed tomography (CT) with iodinated contrast medium and calibrated angiography until the end of 2004. From 2005, CT alone was performed with a multislice scanner (Brilliance 16; Philips Medical Systems, Best, the Netherlands) during bolus injection of iodinated contrast medium (120 mL of Optiray 350; Guerbet, Paris, France) at a 4-mL/s flow rate, followed by 30 mL of saline chaser at the same rate.[7] Parameters for imaging reconstruction sequences were 2-mm slice thickness, 1-mm intervals, 120 kV and variable milliamperes with automatic dose modulation, and detector collimation of

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Table 1. Patient Characteristics.[a]

	Telementored (n=49)	Unmentored (n=86)	p
Men	48 (98.0)	77 (89.5)	0.093
Age, y	71.6	70.9	0.630
Ischemic cardiopathy	17 (34.7)	31 (36.0)	>0.99
Valvular heart disease	6 (12.2)	8 (9.3)	0.573
Arrhythmias	6 (12.2)	6 (7.0)	0.352
Chronic obstructive pulmonary disease	11 (22.4)	9 (10.5)	0.078
Peripheral vascular disease	12 (24.5)	18 (20.9)	0.670
Chronic renal failure	5 (10.2)	19 (22.1)	0.103
Diabetes	7 (14.3)	19 (22.1)	0.365
Arterial hypertension	29 (59.2)	67 (77.9)	0.029
Hypercholesterolemia	12 (24.4)	30 (34.8)	0.249
Smoking habit	24 (48.9)	22 (25.6)	0.008
Neoplasia	10 (20.4)	8 (9.3)	0.117

[a]Continuous data are presented as the means; categorical data are given as the counts (percentage).

16×1.5.[7] Aneurysm diameters, relevant for stent implantation, were measured on multiplanar reconstructions, maximum intensity projections, and 3-dimensional images provided by a satellite workstation (Extended Brilliance Workspace, release 3.5; Philips Medical Systems).[7]

EVAR Protocol

EVAR was performed in a standard fashion.[6,7] In brief, both common femoral arteries were surgically exposed. After hydrophilic guidewire (Terumo Medical Corporation, Somerset, NJ, USA) introduction into the iliac axis, major anatomical landmarks were carefully explored under fluoroscopic control to correctly select the stent-graft. An Amplatz super stiff guidewire (Boston Scientific, Marlborough, MA, USA) was placed to support stent-graft implantation. Stent-graft modeling with a compliant balloon (Cook Medical, Bloomington, IN, USA) was performed to set the device at the proximal neck and at the distal landing zone. Until December 2003, these procedures were performed in the operating room, allowing the use of IVUS for real-time road mapping of the abdominal aorta and major limbs before stent-graft implantation, as well as for postprocedure control. From January 2004, all procedures were carried out in an angiographic suite without IVUS. The procedure duration ranged between 88 and 156 minutes for the telementored group and between 75 and 170 minutes for the unmentored group. The contrast amount was 0 mL per patient in the telementored group (due to the use of real-time IVUS control) and 80 to 240 mL per patient in the unmentored group.

Follow-up Protocol

Similar to previous work,[7] clinical assessment in follow-up included supine abdominal radiography in 3 views, as well as triphasic CT on day 2, at 3, 6, and 12 months, and then annually (every 6 months until 2004).[7] Moreover, since 2003, magnetic resonance imaging (MRI), whenever possible and unless contraindicated or refused, replaced CT beginning at the 3-month follow-up with the aim of reducing the burden of ionizing radiation.[7]

Endpoint Definition and Statistical Analysis

The primary endpoint was overall AAA-related mortality, including both 30-day and late deaths.[9] Primary technical success was defined by correct prosthesis placement without death, conversion to open surgery, type III endoleak,[7,10] vessel rupture, or limb occlusion.[7,9] Further outcomes included the incidence and type of endoleak[7] and complication and reintervention rates, as well as aneurysm diameter evolution during follow-up. Of note, early (within 30 days) and late reinterventions were differentiated. Moreover, the types of reinterventions were distinguished as either percutaneous or endovascular procedures, the latter characterized by surgical exposure of the femoral artery to allow placement of larger introducers.

Continuous variables were summarized as means ± standard deviation while categorical data were presented as counts (percentage). Continuous variables were compared with the Student *t* test for independent samples. The degree of association between categorical data was tested with the chi-square or Fisher exact test. Results are reported with the odds ratio (OR) and 95% confidence interval (CI). Overall survival was evaluated using the Kaplan-Meier method and compared with the log rank test. Normality of survival distributions was verified using the Kolmogorov-Smirnov goodness-of-fit test. A 2-tailed $p<0.05$ was the threshold for statistical significance. Statistical analysis was performed with SPSS software (version 21.0; IBM Corporation, Armonk, NY, USA) and GraphPad Prism (version 5.0; GraphPad Software, San Diego, CA, USA).

Results

The study groups were similar in terms of sex, age, and distribution of comorbidities; the only significant differences were fewer hypertensive patients (59.2% vs 77.9%, p=0.029) and smokers (48.9% vs 25.6%, p=0.008) in the telementored group. Patients were also classified according to EVAR 1[11] and EVAR 2[12] criteria, with no significant difference in the number of EVAR 2 patients between the telementored and unmentored groups (20.4% vs 16.3%, p=0.641).

Technical Results

The perioperative AAA-related mortality was 4.1% in the telementored group (2 deaths due to a common iliac artery rupture and to aortic neck rupture) and 2.3% in the group of procedures performed after the telementoring phase (2 deaths due to retroperitoneal hemorrhage and to iliac limb occlusion with multiple organ failure), with no significant difference between the 2 groups (p=0.621, OR 1.787, 95% CI 0.244 to 13.104). The primary technical success was 93.9% in the telementored group and 97.7% in the unmentored cohort (p=0.353, OR 0.365, 95% CI 0.059 to 2.264). In particular, technical failures were due to 2 deaths and 1 type III endoleak in the telementored group and to 2 deaths in the group of procedures performed after the telementoring phase. One late AAA-related mortality occurred only in the telementored group; an AAA ruptured 86 months after the procedure following type Ia endoleak development. No significant difference was appreciated between telementored and unmentored groups regarding overall AAA-related mortality (6.1% vs 2.3%, p=0.353, OR 2.739, 95% CI 0.442 to 16.989). During clinical follow-up (94.2±43.8 months) in the telementored group, 5 patients were lost to follow-up, 15 patients were still alive, and 29 patients had died. Of these deaths, 3 patients died due to AAA-related causes (the 2 perioperative deaths and 1 late AAA rupture mentioned above), while 26 died because of AAA-unrelated causes (Table 2). Similarly, in the 54.6±28.3-month follow-up of patients treated after the telementoring phase, 1 patient was lost to follow-up, 67 patients were still alive, and 18 patients died [2 perioperatively due to AAA-related causes and 16 of unrelated causes (Table 2)]. In particular, no significant difference could be appreciated when comparing the Kaplan-Meier survival curves between the groups; the estimated mean time of survival was 106 months (95% CI 91 to 120) in the telementored group vs 93 months (95% CI 84 to 102) in the unmentored cohort (p=0.057).

The mean changes in perpendicular AAA diameters over time in the telementored group were −0.03±1.4 cm and −0.18 ±1.3 cm. In the group of procedures performed after the telementoring phase, the mean changes were −0.92±1.3 cm and −1.1±1.3 cm. There were no significant differences between the initial AAA mean diameters, but final AAA mean diameters were significantly lower (p<0.001) in the group of procedures performed after the telementoring phase, with a significantly greater mean sac diameter reduction over time (p<0.001).

There was no significant difference in the number of patients developing endoleaks between the telementored and the unmentored groups (55.1% vs 51.2%, p=0.722, OR 1.171, 95% CI 0.579 to 2.369). Endoleak development was the most frequent complication in both groups (Table 3). In detail, 50 complications were observed in 28 telementored

Table 2. Deaths Unrelated to Aneurysm.

	Telementored (n=49)	Unmentored (n=86)
Cancer	13	3
Hemorrhagic shock[a]	4	1
Myocardial infarction	1	0
Intracerebral hemorrhage	2	2
Unspecified cardiac arrest	1	0
Stroke	1	1
Septic shock	1	2
Suspicion of thoracic aneurysm rupture	0	1
Terminal renal failure	0	1
Unknown cause	3	5
Total	26	16

[a]Related to hemorrhagic enteritis, gastrointestinal bleeding (n=2), bleeding gastric polyps, and aortic valve repair.

Table 3. Complications in the Study Groups.

	Telementored (n=49)	Unmentored (n=86)
Patients, n (%)	27 (55.1)	44 (51.2)
Endoleaks (early and late)	39	52
Ia	14	8
Ib	6	3
Ic	1	0
II	7	24
III	2	0
IV	0	1
V	1	3
Indeterminate	8	13
Right limb occlusion	2	2
Left limb occlusion	2	0
Pseudoaneurysm	2	1
Kinking of the stent-graft	0	2
Distal migration of the main body	2	1
Stent-graft infection	1	2
Vascular dissection	1	0
Periaortic collection	1	1
Vascular stenosis inside the graft	0	2
Postembolization ischemic colitis	0	1
Total complications	50	63

Table 4. Reinterventions in the Study Groups.

	Telementored (n=49)	Unmentored (n=86)	p
Overall	16 (32.7)	10 (11.6)	0.006 (OR 0.271, 95% CI 0.112 to 0.661)
Surgical			
Early	3 (6.1)	3 (3.5)	0.668 (OR 0.554, 95% CI 0.107 to 2.858)
Late	5 (10.2)	2 (2.3)	0.098 (OR 0.210, 95% CI 0.039 to 1.124)
Endovascular			
Late	6 (12.2)	1 (1.2)	0.009 (OR 0.084, 95% CI 0.010 to 0.723)
Percutaneous			
Early	3 (6.1)	1 (1.2)	0.136 (OR 0.18, 95% CI 0.018 to 1.784)
Late	10 (20.4)	6 (7.0)	0.027 (OR 0.293, 95% CI 0.099 to 0.863)

Abbreviations: CI, confidence interval; OR, odds ratio.

patients vs 63 complications in 49 patients from the unmentored group (57.1% vs 57%, p>0.99).

Significantly fewer patients underwent reinterventions in the group of procedures performed after the telementoring phase (11.6% vs 32.7%, p=0.006, OR 0.271, 95% CI 0.112 to 0.661). In particular, there were fewer late endovascular procedures (1.2% vs 12.2%, p=0.009, OR 0.084, 95% CI 0.010 to 0.723) and late percutaneous interventions (7.0% vs 20.4%, p=0.027, OR 0.293, 95% CI 0.099 to 0.863). No significant difference was appreciated between the 2 groups comparing the number of patients who underwent early and late surgical reinterventions or early percutaneous procedures (Table 4).

Figure 1. Telementoring displays from the remote site with 2 of the 3 online video facilities capturing fluoroscopic and intravascular ultrasound images for the experienced mentor (below right).

Discussion

The Society of American Gastrointestinal and Endoscopic Surgeons defined telementoring as the "teaching of the medical art . . . via an interactive audio-video communication system employing tele-electronic devices."[5,13] Since its first pioneering attempt in 1962 with an aortic valve replacement performed by DeBakey in the Houston Methodist Hospital[5,14] and transmitted via satellite to the medical team in the University Hospital of Geneva, telementoring has been exploited worldwide in different fields. Surgical laparoscopic operations,[1,15–19] urologic interventions,[20–22] and endovascular procedures[23] have been telementored over time with positive outcomes, and technical standards for videoconferencing and teletransmission networks have been progressively improved.[5] In particular, the first rudimentary transmission standards (eg, ISDN) have been progressively replaced by high-speed Internet protocol–based communication and fourth-generation mobile phones[2,5] to reduce data latency from source to destination.[5]

In our experience, even basic teletransmission systems, such as ISDN lines, proved effective in supporting the telementoring protocol, preserving procedure safety. Indeed, the 384-kb/s speed connection, albeit terribly slow by today's standards, adequately supported the 2-way audiovisual communication between the local team and the mentor throughout the procedure. In particular, the multiple views of the operating theatre (including views of the surgical field, fluoroscopy, and IVUS; Figure 1) allowed the mentor to supply instructions in case of technical difficulties, such as the measurement of the aortic neck, the detection of the renal artery ostia, or the identification of the proximal/distal attachment zones, while the single view of the mentor allowed demonstration of stent-graft implantation to the telementored team.[6] Of note, the ethical and legal safety of the procedure was similarly guaranteed and clearly stated in the telementoring protocol, without juridical problems. The operators of the remote center were the only ones responsible for the intervention, while the mentor simply assured professional advice and technical suggestions.

In our study, EVAR was safely delivered to a distant hospital, and EVAR skills were assimilated into the routine practice of the remote site. Telementoring thus represented a safe and effective strategy to meet the needs of patients by providing a previously unavailable health care procedure and of the remote operating team by supporting their educational needs.[2,3] Our study results document that the program goals were met. Following the 2 groups over a >10-year period disclosed no significant differences concerning either the technical success rates or perioperative mortality. Though the perioperative mortality in both groups was slightly higher than reported in the main trials comparing EVAR with open surgery,[7,24,25] further studies such as the EVAR 2 trial showed a 30-day mortality ranging up to the 7.3% due to the inclusion of patients with a greater burden of comordities.[26] In our cohorts, >15% of patients met the EVAR 2 criteria, possibly explaining our perioperative mortality.

Similarly, the telementored group showed no significant difference in the overall AAA-related mortality or the number of patients developing complications compared to unmentored procedures. Endoleak development represented the most frequent complication in both groups, with incidences slightly higher than data reported in the literature.[7,27–29] However, surveillance favored the use of MRI when feasible, which has greater sensitivity for endoleak detection (compared with CT).[7,30,31] Finally, there was a significantly greater mean sac diameter reduction over time in the group of procedures performed after the telementoring phase.

Fewer patients underwent secondary interventions in the unmentored group, with a significantly lower number of patients undergoing late endovascular or percutaneous interventions. Such results testify to the high level of EVAR skills assimilated into the routine clinical practice of the remote site, with significant technical improvement over time as the learning curve of the remote team was surmounted. Therefore, the clinical and educational goals were met independent of the geographical distances and without the resources and time constraints related to sending mentors to the remote sites.

Limitations

Several limitations should be taken into account. Our study did not employ any randomization strategy or a control group, which would have involved a greater number of patients and a multicenter approach. For this reason, the 2 groups, albeit showing a quite similar distribution of comorbidities, were not homogeneous. No cost-benefit analysis was performed to statistically compare the telementoring program to traditional mentoring and on-site teaching. Moreover, our data should be carefully generalized to other clinical settings since the telementoring program had been established between 2 teams highly experienced in telemedicine projects[32,33] and with long-lasting close cooperation persisting even beyond the telementoring phase. In addition, teleconferencing equipment has improved immensely since this program was initiated with ISDN lines. However, the fact that even basic teletransmission systems proved effective in our telementoring protocol suggests that telemedicine could be even more successful when supported by modern transmission standards. Finally, data on reinterventions could have been biased by the shorter follow-up period in the unmentored group.

Conclusion

Our telementoring program permitted safe delivery of EVAR in a remote clinical setting while inculcating EVAR skills into the routine practice of the remote site. In addition, the incorporated EVAR skills of the telementored team improved further as demonstrated by the lower rate of reinterventions after the telementoring phase. Telementoring thus represents an excellent example of the use of telemedicine for on-site teaching in remote health care sites.

Authors' Note

This study was presented at the Congress of the Swiss Society of Cardiology (June 15–17, 2016; Lausanne, Switzerland).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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